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EXPLORING THE EFFICIENCY AND EFFECTIVENESS OF AN AUTOMATED ROBOTIC VACUUM CLEANER

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Abstract:
As advancements in technology continue, people are seeking ways to automate tedious tasks to save time and energy. Recently, robots have become a significant area of research in robotics because of their high productivity and usefulness in assisting humans. Typically, robotic cleaners are recognized for their cleaning capabilities. Some robots are equipped with proximity sensors to help them avoid obstacles, while others use laser mapping techniques. Currently, two main types of automated vacuum cleaners are available: VSLAM-based and LIDAR-based. While VSLAM is more cost-effective, its mapping capabilities are not as advanced as LIDAR. On the other hand, LIDAR offers better mapping accuracy, but is more expensive. With our project, we aim to create a combination of both the above mentioned technologies, i.e it will be cost effective but have a mapping almost as good as LIDAR.

***Keywords* —** Intelligent Floor Cleaning Robot, VSLAM, Automation, 3D Sensing, Raspberry Pi, Arduino, Vacuum Dusting, Collision Prevention, Path Planning

I. INTRODUCTION

In recent years, scientists have been looking for ways to make household tasks, such as floor cleaning, faster and more efficient. To this end, robots have become increasingly common in households. There has been a significant rise in the use of technologies like IOT, microcontrollers, and microprocessors like Arduino, Atmega, 8051, and Raspberry Pi to develop and design robotic vacuum cleaners. Microcontroller-based automated vacuum cleaner robots are becoming increasingly popular due to their ability to perform cleaning tasks quickly and efficiently. These robots are equipped with microcontrollers, sensors, motors, and other components that enable them to detect obstacles in their path and autonomously navigate around them. They can also be programmed to clean specific areas and are increasingly being used in homes and businesses to reduce the need for human intervention. This kind of technology eliminates the need for human intervention, thereby reducing errors and the time taken to complete tasks.

II. LITERATURE SURVEY

The first study [1] that was analyzed in the review had a robotic vacuum cleaner as the main subject. It was controlled by Arduino Leanardo and had ultrasonic sensors that helped it navigate through obstacles. The data from the sensors was used to guide the brush motors and prevent collisions with wheel motors.

The second study [2] that was looked at incorporated IoT technology and a microcontroller 8051, as well as a smart bin and vacuum cleaner. This system was designed to separate waste using 8051 and a moisture sensor, as well as the vacuum cleaning process. Ultrasonic sensors were used to determine if the dustbins were full and a GSM module was used to send a text message to the designated user when the bins needed to be emptied.

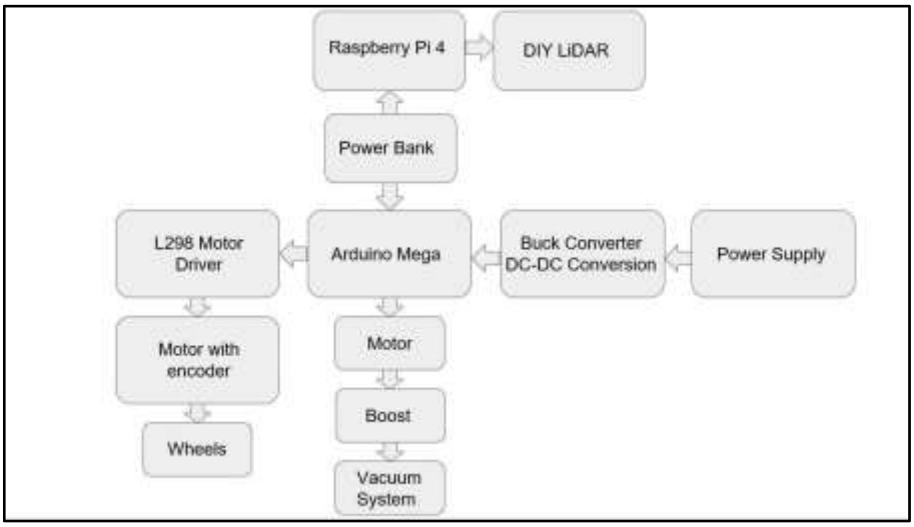
In the third paper [3], the project utilizes Arduino, a Wi-Fi module, and proximity sensors to construct a vacuum cleaner robot. When the robot is powered, the motor drivers will begin working, allowing the robot to move forward. However, if an obstacle is detected within 3 cm of the robot, the command is given to reverse the motor operation, thus allowing the robot to move in the opposite direction.

The fourth paper [4] details the design of a vacuum system that utilizes both Raspberry Pi and Arduino as its primary controllers. The use of LIDAR for mapping and proximity sensors for path generation allows the robot to autonomously navigate its environment. Additionally, a GPS module is used for positioning and the authors have implemented an autonomous process for battery recharging, called ‘auto docking and charging process’, which eliminates the need for human assistance, making the robot fully autonomous.

III. DESCRIPTION OF SYSTEM

1. *Block Diagram*

The Arduino Mega and Raspberry Pi are linked through a serial cable, which is used to transfer data between the devices using serial communication protocol. Serial communication involves transmitting data one bit at a time in a sequential order over a communication channel or computer bus. The Arduino Mega controls the two motors through the motor driver. The motor driver is a device that is made to regulate the speed and direction of two motors simultaneously. It is constructed using the L293D IC, which is a 16 Pin Motor Driver IC. This IC is created to give bidirectional drive currents that range from 5V to 36V. The Raspberry Pi with DIY LIDAR is a high-level controller which issues commands to the Arduino, which is a low level controller. This configuration makes sense because the Arduino is better suited to interact with the motors and motor driver. We use Li-ion batteries for power supply. We also use a power bank for Raspberry Pi and LIDAR. The motor which is connected to the Arduino is boosted for a better vacuum system. If an obstacle (wall, furniture, etc) gets detected by the LIDAR, it sends that data to the Raspberry Pi. The Raspberry Pi uses the genetic Algorithm for internally computing and commanding the robot.The Raspberry Pi then sends messages to the Arduino to either take turns towards the left or the right, or to continue to move forward and clean the mapped area.



2. *Electronic System*

- ***LIDAR***

Lidar is a technique used to measure the distance to an object or surface by targeting it with a laser and measuring the time it takes for the reflected light to return to the receiver. It can also be used to create digital 3-D representations of areas on the Earth's surface and ocean bottom by varying the wavelength of light. It is suitable for terrestrial, airborne, and mobile applications. Lidar utilizes ultraviolet, visible, or near-infrared light to image objects and can target a wide range of materials, including non-metallic objects, rocks, rain, chemical compounds, aerosols, clouds, and even single molecules. A narrow laser beam can map physical features with very high resolutions, allowing an aircraft, for example, to map terrain with a resolution of 30 centimeters (12 inches) or higher.

- ***INFRARED SENSOR***

  Infrared sensors are electronic devices that emit a signal in order to sense and detect aspects of their environment. [5] They can be classified into two types, active and passive. Active infrared sensors consist of both a transmitter and receiver, and can use either a light-emitting diode (LED) or laser diode as a source. On the other hand, passive infrared sensors include only receivers and use an external object, such as an infrared source, to emit energy, which is then detected through the receivers.
- ***ULTRASONIC SENSOR***

  The HC-SR04 is an ultrasonic sensor that utilizes sonar technology to measure the distance between an object and the sensor. It has an excellent noncontact detection range and provides precise and reliable measurements.
- ***MICROCONTROLLER***

  The ATmega2560 is a low-power CMOS 8-bit microcontroller built on an AVR enhanced RISC architecture. It is able to process powerful instructions in a single clock cycle, allowing for maximum efficiency with minimal power consumption. It contains an 8-bit RISC CPU with In-System Self-Programmable Flash, providing a cost-effective solution for many embedded control applications. Its high speed and flexible design make it an ideal choice for many applications.
- ***MOTOR DRIVER***

  The L298N is an integrated monolithic circuit consisting of two H-bridge motor drivers in a single package. [6][9]It is a high voltage, high current dual full-bridge motor driver designed to accept TTL logic levels. It has separate enable pins for each bridge, enabling and disabling them individually. The emitters of the lower transistors of each bridge are connected together and can be used to connect external sensing resistors. It can drive a DC motor with a maximum current of 4A and operates on a supply voltage up to 46V. It also has an inbuilt overtemperature protection feature which protects the circuit when the internal temperature exceeds the maximum operating temperature limit.
- ***GEARED MOTORS***

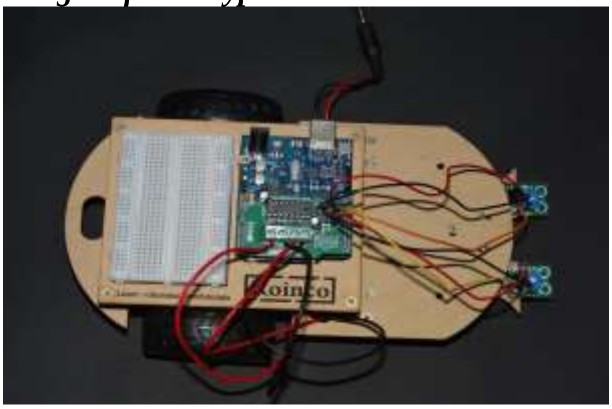
  The 100 RPM Single Shaft BO Motor - Straight offers great torque and speed at lower operating voltages, making it a great choice for many applications. It features a small shaft with matching wheels for an optimized design that is suitable for in-circuit placement. The motor can be used with a 69mm Diameter Wheel for Plastic Gear Motors and is an alternative to metal gear DC motors. It operates on a voltage of 3-12V and is great for building small and medium sized robots.
- ***BUCK CONVERTER***

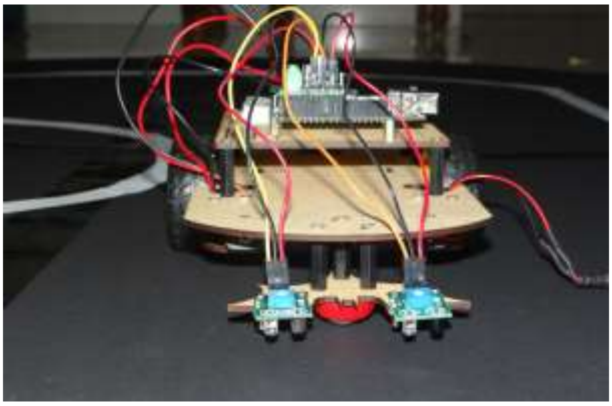
  The LM2596 DC-DC Buck Converter Step Down Module is a switch-mode power supply that offers high efficiency and is capable of driving a 3-A load with excellent line and load regulation. It operates at a switching frequency of 150kHz, allowing for smaller filter components than what would be required with lower frequency switching regulators. This module is equipped with a high precision potentiometer, and can work with Freeduino UNO, other mainboards, and basic modules. It is internally compensated to reduce the number of external components needed to simplify the power supply design. When the output current is greater than 2.5A (or output power is greater than 10W), it is recommended to add a heat sink. Compared to three-terminal linear regulators, the LM2596 converter offers significantly higher efficiency, especially with higher input voltages.

- ***RASPBERRY PI***

  The Raspberry Pi 4 has undergone extensive compliance testing and meets a variety of regional and international standards. [7][8] The most impressive change for the Pi 4B is that it is available with three different amounts of fast DDR4 SDRAM memory; 1GB, 2GB, or 4GB. This, combined with its faster 1.5GHz quad-core processor, allows the Pi 4B to run large programs and tasks more quickly than before. It also has Bluetooth 5.0, two USB 3.0 ports, and true Gigabit Ethernet for fast wireless and wired communication. The dual-band wireless LAN now comes with modular compliance certification, enabling the board to be integrated into end products with reduced compliance testing, which can improve both cost and time to market.

3. *Images of Prototype*





IV. EXPERIMENTATION AND RESULTS

Based on our prototype, three studies were carried out. Basic component functionality was examined in the first experiment. The robot's mechanical, electrical, and control components underwent testing to ensure proper operation."1" denotes proper operation, while "3" is the highest possible value, indicating that all system components operate effectively. 100% of the findings for this trial indicated that every component was operating effectively. The robot's ability to clean was tested in the second trial. In this experiment, the robot is operated manually, and a specific amount of garbage is put in a predetermined location.

$$\text{cleaning performed by the robot} = \frac{\text{weight of content}}{\text{total content weight}} * 100$$

The outcomes of this experiment fluctuated between 2-68%.

Attempt No.	Type of Waste	Waste Collected (in gms)	Efficiency
1	Wet Waste	1.27	2.54
2	Wet Waste	2.31	4.62

3	Wet Waste	2.91	5.83
4	Wet Waste	1.30	2.61
5	Dry Waste	22.14	44.28
6	Dry Waste	24.23	48.47
7	Dry Waste	22.31	44.62
8	Dry Waste	21.54	43.09
9	Plastic Waste	31.09	62.19
10	Plastic Waste	29.18	58.36
11	Plastic Waste	34.34	68.69
12	Plastic Waste	32.40	64.81

During the third experiment, the robot's ability to avoid collisions was evaluated using the formula:

$$\text{Rate of Collisions} = \frac{\text{number of collision taking place}}{\text{number of obstacles placed in the environment}} * 100$$

The outcomes of this experiment fluctuated between 20-50%. On the whole, the robot system demonstrated an efficiency level of 68% when tested in a controlled setting.

The battery system for the robot consists of two packs of 10 cells each, which are 3.7V and 3600mAh Li-ion batteries. Each pack has 10 cells connected in series, creating a total voltage of 37V. When the two packs are connected in parallel, the current rating is increased, resulting in a total capacity of 7200mAh or 7.2Ah, and an input power rating of 266.4Wh. The robot's power consumption is 30W for the vacuum system and 72W for 4 DC geared motors, for a total consumption of 102W. If fully charged, the robot can operate continuously for 3.7 hours. However, the robot has the capability for autonomous docking, meaning it can recharge itself without human intervention, making the battery life less of a concern.

V. CONCLUSIONS

After thorough prototyping and testing, it is evident that automated robotic vacuum cleaners have undergone modern development processes, where new technologies such as Arduino and Raspberry Pi have been implemented and tested. Integrating these technologies with IOT, modern sensors and motors has allowed for a more efficient cleaning process at a lower cost. [10]The drawback is that these devices are not fully autonomous, and require some human involvement. This issue can be resolved by incorporating advanced technologies such as Artificial Intelligence and Machine Learning in computer science. Algorithms are used in some cases for optimization, but this is not as effective as what Machine Learning can provide. By employing Machine Learning technologies such as Object Detection, we can further optimize the performance of these devices. We will construct an IOT-based ARVC that can function effectively in an unfamiliar environment by utilizing a makeshift LIDAR system. [11]This will enable the robot to map out the room with precise and accurate detail, leading to improved cleaning with fewer collisions and more efficiency. This robot will minimize human interaction and effort when it comes to household cleaning, allowing for a more productive and comfortable lifestyle.

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